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Dynamic flow method to study the CO_2 loading capacity of amino acid salt solutions

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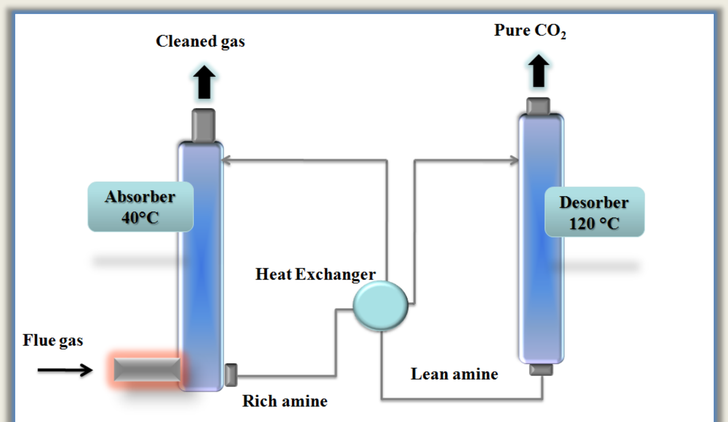
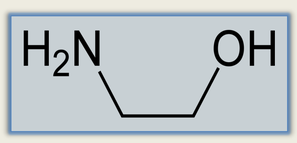
CO_2 capture from flue gas by chemical absorption

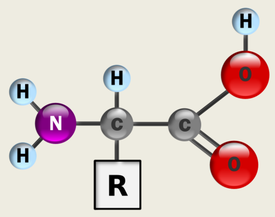


Absorber: The CO_2 in the flue gas is chemically bound to the solvent (typically a solution of amines) and the cleaned gas is emitted to the air.

Desorber: The CO_2 loaded solvent (Rich amine) is heated to ~120 ºC, whereby the CO_2 is released. The solvent (Lean amine) is circulated back to the absorber for another round of CO_2 capture. The pure CO_2 product form the desorber is compressed and send to storage.



Mono-ethanolamine (MEA)
The amine most widely used for CO_2 capture

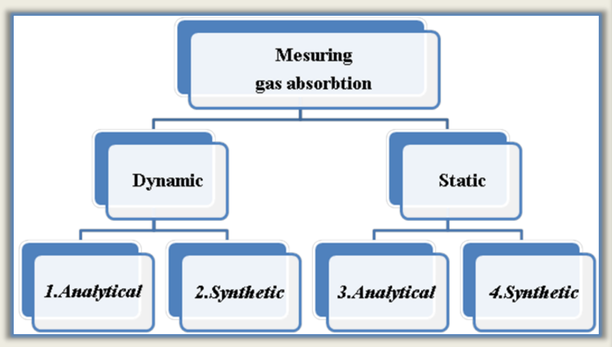


General structure of an amino acid

The amines normally used for CO_2 capture (such as MEA) entails both economical and environmental complications.

Amino acid salt solutions are promising new types of solvents for CO_2 capture.

Categorization of experimental methods used for measuring CO_2 gas absorption



Dynamic : A continuous flow of gas into the cell is maintained during the experiment.

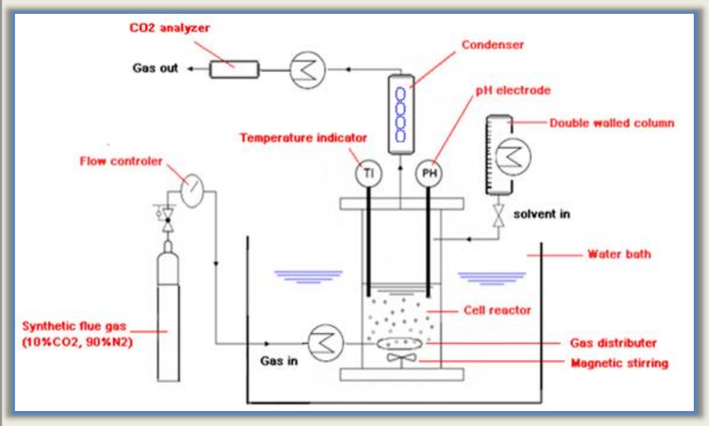
Static: The cell is filled with a known amount of gas, at the start of the experiment.

Analytical : The composition of the phases at equilibrium, are determined analytically.

Synthetic: The composition of the phases at equilibrium are based on indirect measurements, such as pressure, temperature, phase volumes and densities, which are subsequently used in calculations involving material balances.

Experimental set-ups used for studying CO_2 absorption by amino acid salt solutions

Dynamic & Analytical set-up (Dynamic flow set-up)

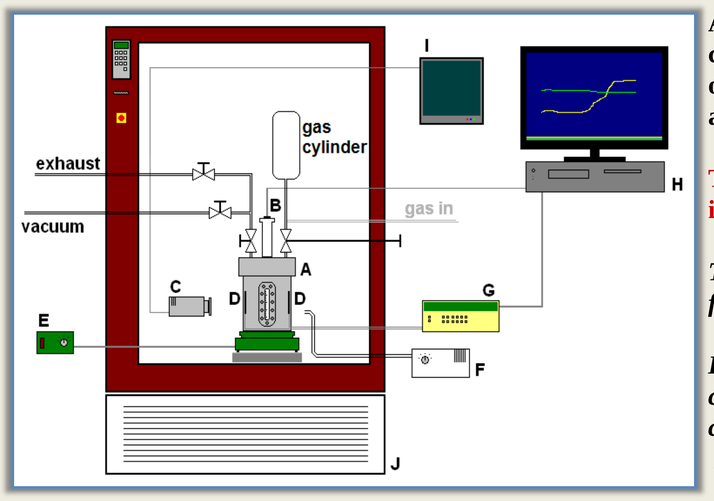


A gas mixture, containing approximately 10% CO_2 is continuously bubbled through the solvent, at a total pressure very close to atmospheric pressure.

The effluent stream is analyzed for its concentration of CO_2, using infrared (IR) spectroscopy.

The amount of CO_2 absorbed, is found by integrating over time, the concentration of CO_2 in the effluent stream.

Static & Synthetic set-up



A known amount of CO_2 is put into the gas cylinder. The experiment is started by opening the valve between the gas cylinder and the cell (A) containing the solvent.

The amount of CO_2 absorbed is measured indirectly:

The volume of the gas phase at equilibrium is found using the camera (C) with monitor (I).

Knowing the density of CO_2 gas at equilibrium conditions, the mass of CO_2 absorbed is calculated:

$Mass_{CO_2\ absorbed} = Mass_{CO_2\ added} - Mass_{CO_2\ gas\ phase\ at\ equilibrium}$

[José M. S. Fonseca. Ph.D. Thesis, CERE -Centre for Energy Resources Engineering Department of Chemical and Biochemical Engineering, Technical University of Denmark, 2010].

Using the dynamic flow set-up to study CO_2 absorption of 4 amino acid salt solutions

1. Validation of the dynamic flow set-up with MEA

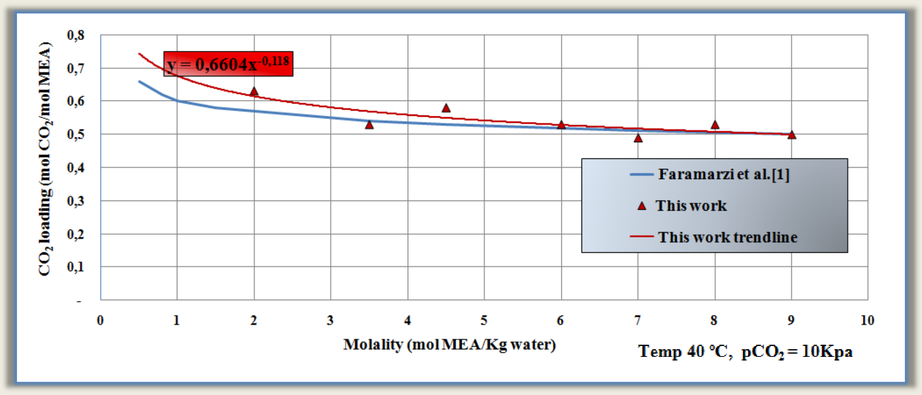


Figure 1: Validation of the dynamic flow set-up using aqueous solutions of (MEA) with concentrations between 2-8 molal. The experimental conditions were 40 ºC, partial pressure of CO_2 ~ 10 kPa, and total pressure ~ 100 kPa.

The obtained data were validated against calculations of the Extended UNIQUAC thermodynamic model [Faramarzi et al. Fluid Phase Equilibria (2009)].

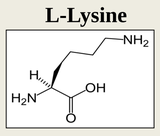
MEA represents a benchmark solution to which all new solvent will be compared.

Testning 4 amino acids

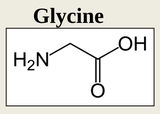
CO_2 absorption by aqueous solutions of the potassium salt of the 4 amino acids: L-lysine, glycine taurine and L-proline.

Figure 2 & 3: The amino acid salt solutions were tested over the concentration range 2-7 molal. The figures show similar results for MEA. The experimental conditions were: 40ºC, partial pressure of CO_2 ~ 10 kPa, and total pressure ~ 100 kPa.

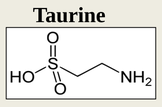
L-Lysine



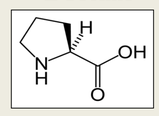
Glycine



Taurine



L-Proline



2. CO_2 loading capacity

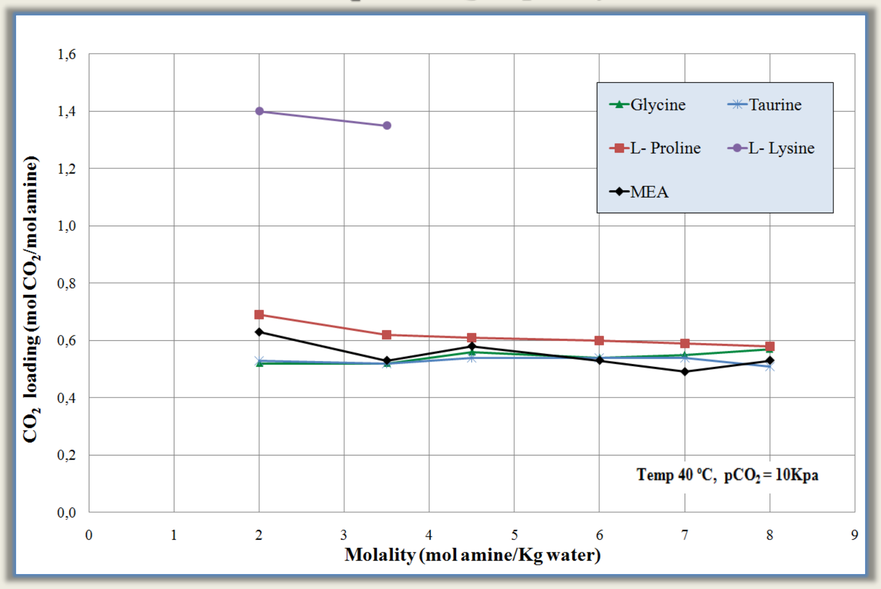


Figure 2: Loading capacity (mol CO_2/mol amine) for the 4 amino acid salt solutions, as well as for MEA, over the concentration range 2-7 molal. The unit, mol CO_2/mol amine is the typically way of presenting CO_2 absorption ability.

3. CO_2 capacity

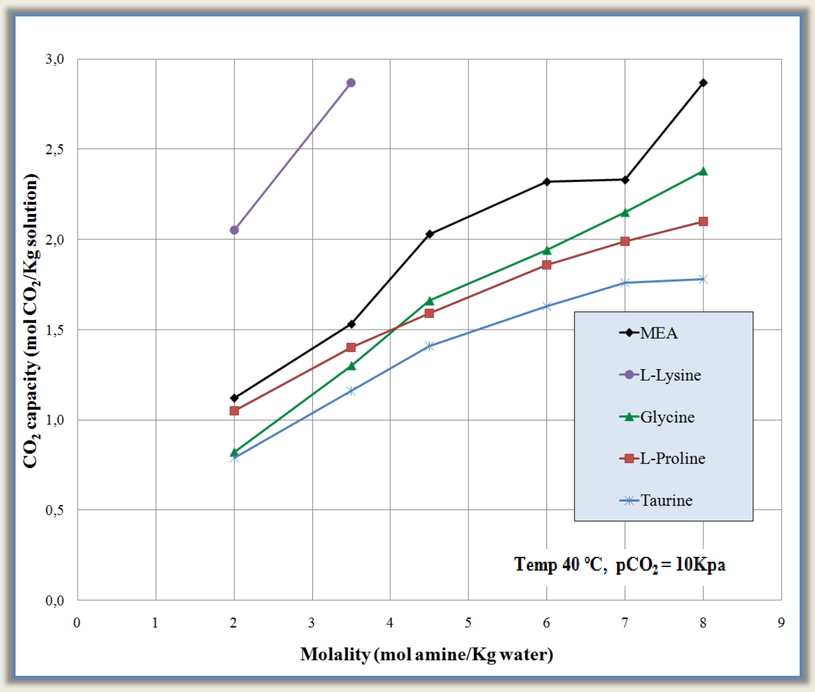


Figure 3: Capacity (mol CO_2/Kg solution) for the 4 amino acid salt solutions, as well as for MEA, over the concentration range 2-7 molal. The unit, mol CO_2/Kg solution gives information about how much solution is needed to be circulated in the CO_2 capture system.

Conclusions:

- **The amino acids tested show good CO_2 absorption ability when compared with MEA.**
- **L-Lysine offers high CO_2 absorption ability due to the 2 amino groups.**

Future work:

- **Further experiments with the dynamic flow set-up.**
- **The Static & Synthetic set-up presented above will be used to study the cyclic CO_2 absorption and regeneration ability of amino acid salt solutions.**